

Basic Application of the EFDR1**INTRODUCTION**

The EFDR1 is a stand-alone, configurable fan controller designed for use on mobile equipment. It is designed to control a hydraulic cooling fan through a proportional solenoid valve. It has a reversing output that can reverse the direction of the fan through a solenoid directional valve. Temperature is monitored through a configurable input that handles the following input signals:

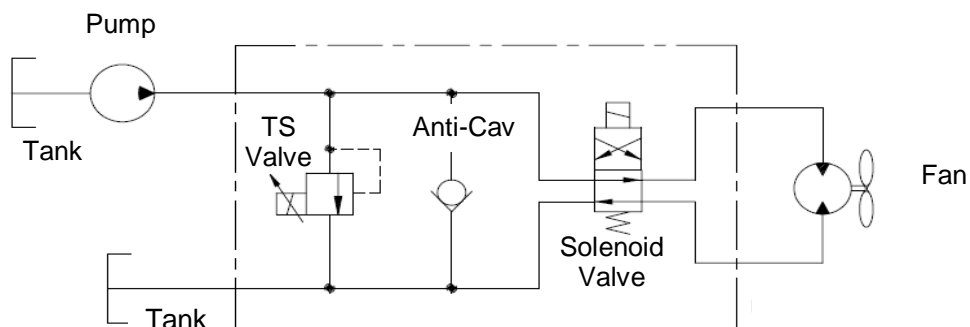
- Non-Linear Resistive
- Linear Resistive
- Pulse-Width-Modulated
- 0 – 5V Voltage
- 0 – 10V Voltage
- 4 – 20 mA Current

This Application Note will describe the implementation of the EFDR1 in a basic reversible fan system. The system uses a non-linear thermistor input for temperature monitoring.

HYDRAULIC CIRCUIT

The hydraulic circuit is shown in FIGURE 1. The normally-closed TS10-27 with an ER-coil is used to control pressure to the fan motor, and is driven by the EFDR1's primary or proportional output. With zero current applied to the TS-valve coil, the system pressure is at maximum thus providing maximum pressure to the fan motor. This zero current condition correlates to a maximum fan speed condition which equates to a maximum cooling condition. As current is applied to the TS-valve coil, the system pressure decreases, thus reducing pressure at the fan motor. This reduced pressure setting correlates to a reduced fan speed thus decreasing the cooling condition. The system also uses a CV08-20 to prevent cavitation of the motor.

The SV10-40 valve is used to switch the direction of the fan motor. The fan reversal option is driven by the EFDR1's secondary or reversing output. This feature provides the operator with the ability to blow off debris when operating in dirty conditions. On the conclusion of a reversing cycle the EFDR1 will induce a ColdShot to the TS valve; meaning the coil is hit with zero current momentarily to ensure that after a reversing cycle an unexpectedly low temperature and resulting minimum pressure will not cause the fan motor to stall. Once the predetermined ColdShot time has elapsed, current to the TS valve adjusts to the temperature dependant operating current, and therefore ensures the continuous and efficient operation of the fan drive motor.

**FIGURE 1: Hydraulic Schematic**

ELECTRICAL CIRCUIT

The wiring diagram is shown in FIGURE 2. The EFDR1's primary output (2-pin connector) plugs into the TS10-27, which controls the fan speed. The secondary output (pins 1 & 6 on the 6-pin connector) is wired to the SV10-40, which reverses motor direction.

The temperature sensor in this application is the ERT150 thermistor. It is a non-linear resistive sensor with a negative temperature coefficient, meaning its resistance decreases as temperature increases. This sensor will be further examined later. The temperature sensor is wired to the EFDR1's input pins (pins 2 & 3 on the 6-pin connector).

In addition to the temperature sensor, there is also a momentary switch in series with a 50 Ω resistor. The switch and resistor are wired in parallel to the temperature sensor to the EFDR1's input pins. This switch/resistor combination is used for the reversing function. When the switch is pressed, the EFDR1 sees the 50 Ω resistance at its input and enables reversing mode by slowing down the fan and turning on the secondary output.

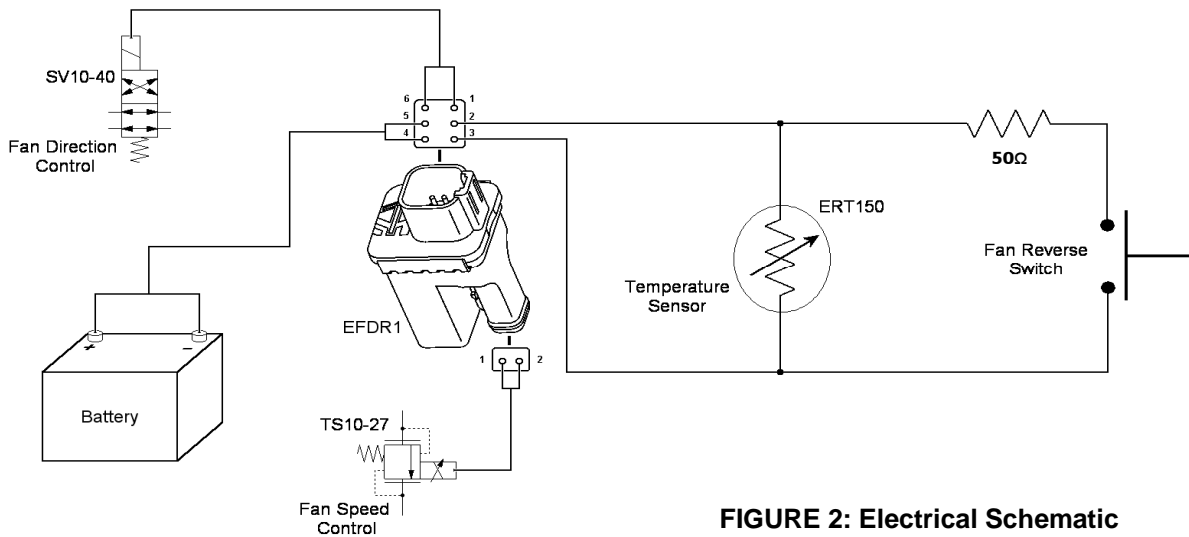
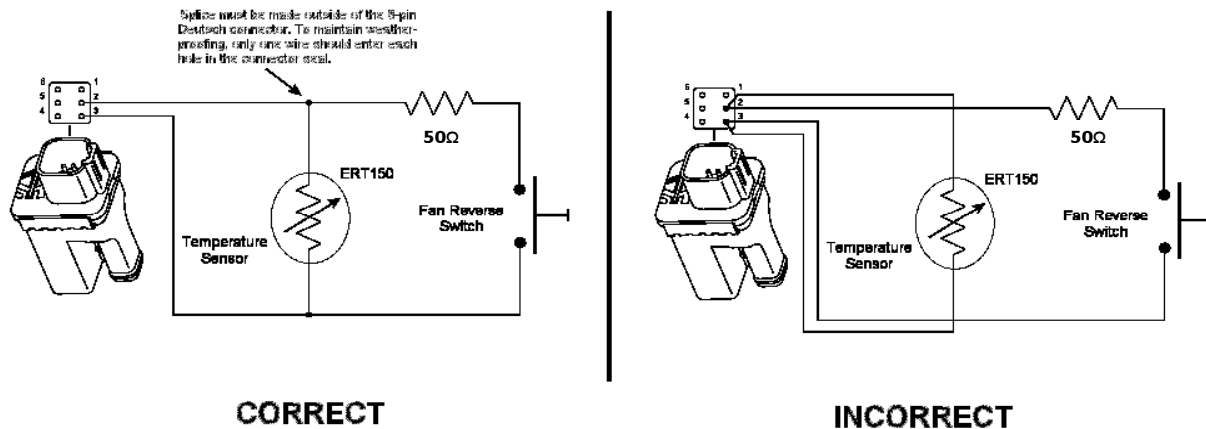


FIGURE 2: Electrical Schematic

WARNING: The temperature sensor wires and the reversing switch/resistor wires must not be fed together into the 6-pin Deutsch connector that plugs into the top of the EFDR1. They should instead be spliced outside of the connector and fed in as single wires. This is required to maintain the connector's IP65 weather rating. See FIGURE 3.



CORRECT

INCORRECT

FIGURE 3: Proper Input Wiring

EFDR1 CONFIGURATION

The temperature sensor used in this application is the ERT150. Some of the sensor parameters, as well as a resistance curve, are shown in TABLE 1. This information is required to configure the EFDR1 for use with this temperature sensor.

Temperature Range	-40°C to 150°C	
Resistance Range	26246 to 33.89 ohms	
Resistance @ 0°C	2768 ohms	
Resistance @ 120°C	63.69 ohms	
Steinhart-Hart Constants		
A	1.426654 E-03	
B	2.69848 E-04	
C	1.86111 E-07	

TABLE 1: ERT150 Temperature Sensor Data

Steinhart-Hart Constants are values associated with a non-linear temperature sensor which describe that sensor’s response curve. Using a mathematical formula, one can use a sensor’s Steinhart-Hart Constants to calculate that sensor’s relative resistance to any temperature.

When configuring the EFDR1 for a non-linear temperature sensor, all the user has to do is enter the Steinhart-Hart Constants and the EFDR1 uses those to calculate the temperature-resistance relationship. This simplifies configuration of the EFDR1 because the output profile is configured in relation to temperature, not resistance.

For the purposes of this application, it’s assumed that the machine will operate in an environment that never falls below 0°C and the oil temperature never rises above 120°C. According to TABLE 1, the expected resistance range of the temperature sensor will be 63.69 to 26246 ohms.

FIGURE 4 shows the pressure vs. current graph for the TS10-27. The maximum control current for a 12-Volt TS10-27 is 1.1 Amps. For this application, the current range for the TS10-27 will be 0.1 to 1.2 Amps.

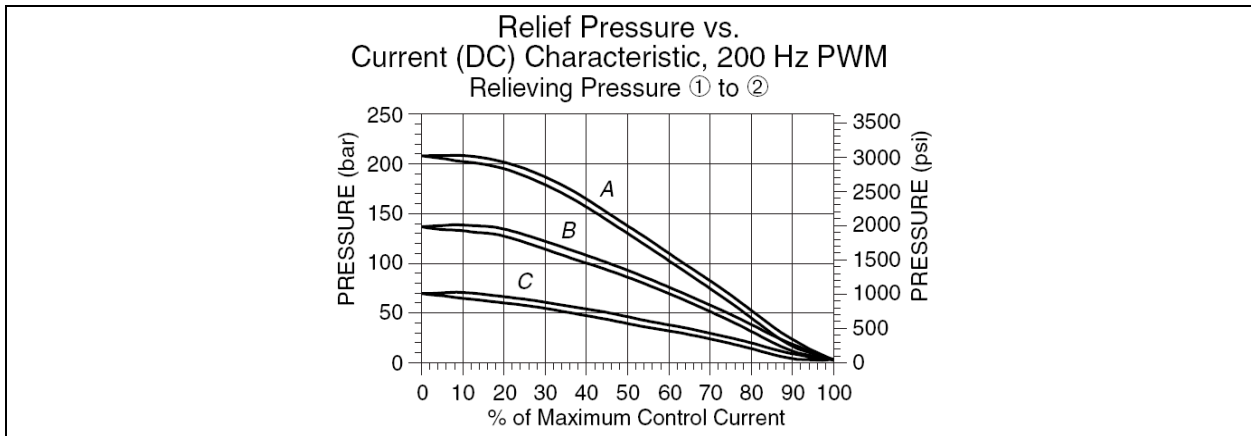


FIGURE 4: Pressure-Current Relationship for TS10-27

FIGURE 5 shows the EFDR1's Program Controls and various Input, Control, Output, and Reversing Parameters. TABLE 2 lists the definition behind setting each of the parameters.

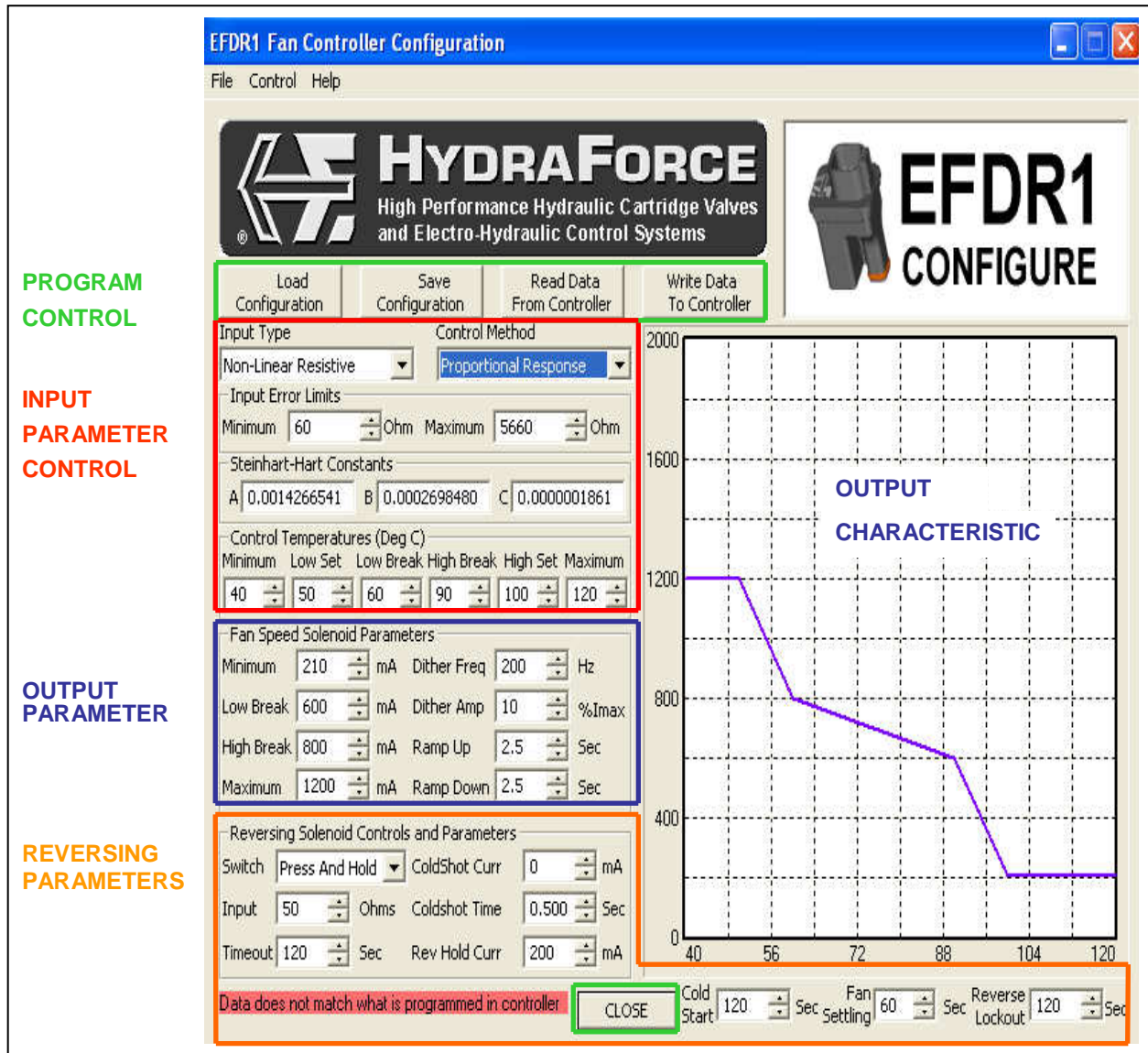


FIGURE 5: EFDR1 Configuration Parameters

Parameter	Setting	Definition
INPUT		
Input Type(s)	Non-linear Res.	This application uses the ERT150, which is a non-linear, resistive temperature sensor.
	Linear Resistive	For applications utilizing a proportional resistive temperature sensor
	PWM Duty Cycle	For applications utilizing a PWM transmitting sensor
	0-5 Volts 0-10 Volt	For applications utilizing a voltage transmitting sensor
	4-20 mA	For applications utilizing a current transmitting sensor
Control Method	Proportional Response	The EFDR1's output will respond proportionally to the input temperature. <i>See FIGURE 5 for output characteristic</i>
	On/Off Response	The EFDR1's output will step between discrete current levels depending on input temperature. <i>See below for output characteristic</i>
Input Error Limits Min/Max	60/5660Ω	The expected resistance range seen by the EFDR1 in this application has been established as 60-5660Ω. If this resistance falls below 60Ω or above 5660Ω, then an error will occur. (The units of measure will change based on the "Input Type" selected. Range is 60Ω-6500Ω)
Steinhart-Hart Constants A/B/C	See TABLE 1	These are the Steinhart-Hart Constants for the ERT150 from TABLE 1. (These constants are only used for the non-linear resistive input type.)
Control Temperatures Min/Max	0°C/120°C	This is the temperature range over which the EFDR1 will operate. Taken from Table 1 in this application.
Set-point and Breakpoints	See FIGURE 5	There are two set-points and two breakpoints (High and Low), each defined by a temperature and desired output current. These parameters define the behavior of the EFDR1 over its operational temperature range. The graph on the configuration tool shows a visual representation of these parameters. By looking at the graph, these parameters have been set to maintain oil temperature between 60°C and 90°C. In this range the EFDR1 has a more subtle response. When temperature goes outside of this range, the EFDR1's response becomes more aggressive in an attempt to get the temperature to return to the desired range.

OUTPUT		
Min/Max Output Current	210mA-1200mA	The output current range EFDR1 in this application has been established as 210mA-1200mA. If this current falls below 210mA or goes above 1200mA an error will occur. See FIGURE 5 for output characteristic. (Output Current range is 0mA/2000mA).
Dither Frequency/ Amplitude	200 Hz / 10%	These are the recommended values for the TS10-27 per the HydraForce catalog.
Ramp Up/Down Time	2.5 secs.	These values will provide a smooth transition of the output. (Ramp Time range is 0-10 seconds).
REVERSING		
Reverse Switch Type	Press and Hold Momentary Auto Over Temp	In this application, a momentary switch is pressed and held to initiate reversing. Reversing will operate until the switch is released or until the Reverse Timeout duration has passed. Alternatively, a momentary type switch can be used, wherein reversing is actuated and will run through a full reverse cycle upon depressing the switch. A switch is unnecessary in this mode, the reversing function will automatically actuate when the Maximum Control Temperature is reached
Reverse Resistance	50Ω	This is the value of the reversing resistor. (Reverse Resistance range is 20-50Ω).
Reverse Timeout	2 minutes	This is the maximum amount of time the reversing function will be on. Reverse Timeout can be set anywhere between 1 second to 2 minutes.
Reverse Hold Current	200mA	The Reverse Hold Current (Range 0-2000mA), is used to limit power consumption on the reverse valve coil when the reverse cycle is started.
ColdShot Current	0mA	Upon completion of a reversing cycle, the TS Valve is initially hit with the ColdShot Current (0mA) for the set ColdShot Time duration (Range 0-2000mA, 0-5 seconds), after which time the valve ramps back up to the predetermined Fan Speed parameter setting.
ColdShot Time	.5 seconds	
Cold Start Time	2 minutes	Cold Start Time is intended to allow the temperature sensor to warm-up so that its resistance falls within the EFDR1's readable range. In this application, the sensor's resistance isn't expected to go above 2768Ω, so no warm-up time is needed. (Some sensors or in extreme temperatures, the sensors resistance can be outside the EFDR1's readable range, which goes up to ~6500Ω, thus sending a false error signal which defaults to maximum cooling. This maximum cooling condition will increase actual machine and oil warm up time.)
Fan Settling Time	60 seconds	This gives the fan time to spin down or decelerate before changing direction. (Independent of Ramp – time starts once ramping is complete. Range is 0-600 seconds.)
Reverse Lockout	2 minutes	This is the amount of time the reversing function will be disabled after a fan reversal has been initiated. (Reverse Timeout can be set anywhere between 1- 900 seconds).

TABLE 2: Configuration Parameters

WARNING: The parameters in FIGURE5 are just a starting point. The Set-points and Breakpoints will likely have to be tuned by trial-and-error until the system operates as desired.

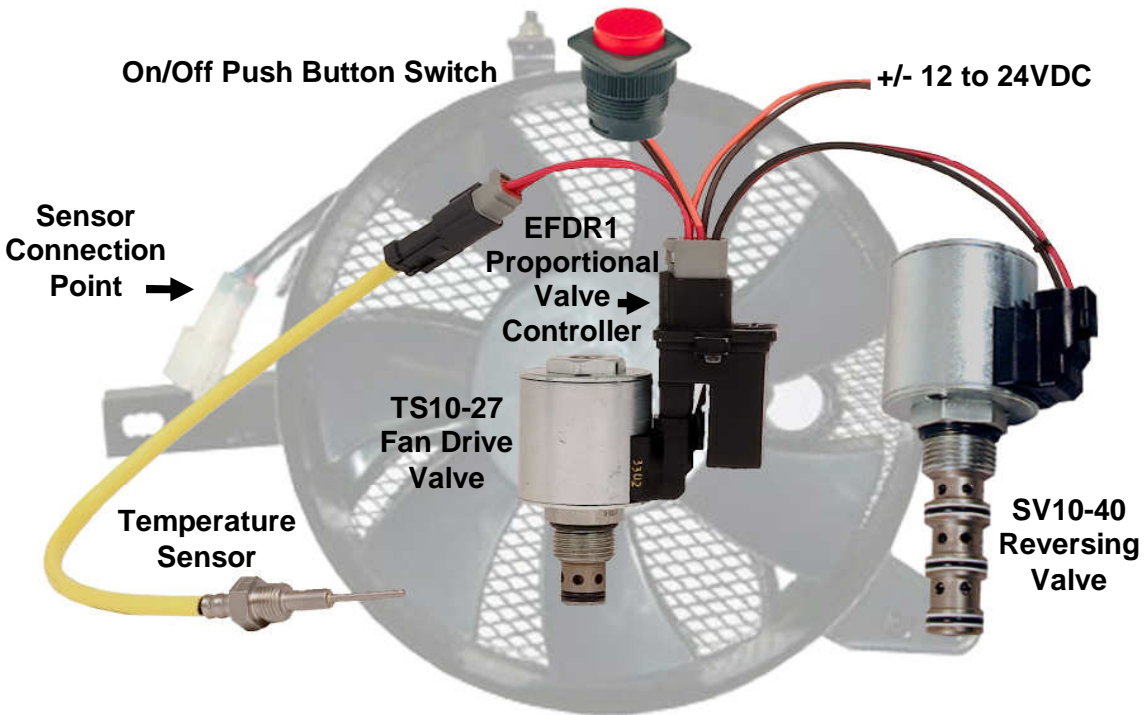


FIGURE 6: Electro-Hydraulic Proportional Fan Drive Control Wiring Circuit

Application guide limitations:

This Application guide is a preliminary document showing a specific example of how HF intends the EFDR1 to be used and operated. The input/output fields, parameter names and ranges are subject to change without notice. Although we do not foresee any performance or actual driver specifications changes, the Graphical User Interface (GUI) may change.

A complete user's manual will be written upon final release of the GUI.

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